Simulating Tropical Tropopause MLS H_2O: How Important is Microphysics?

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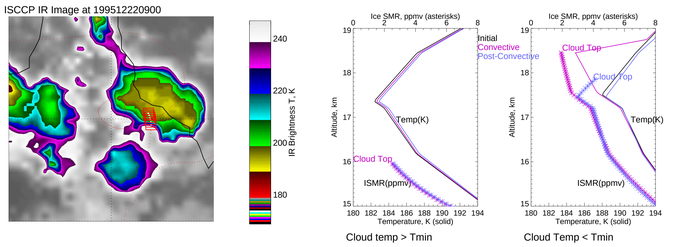
Introduction

Our objective is to understand processes controlling tropical tropopause layer cloud formation and dehydration of air entering the stratosphere. Numerous recent trajectory studies simply assume that any H_2O in excess of the saturation mixing ratio is immediately removed from the atmosphere by ice cloud formation and sedimentation. By comparing simulated TTL water vapor with AURA MLS measurements, we attempt to address the following science questions:

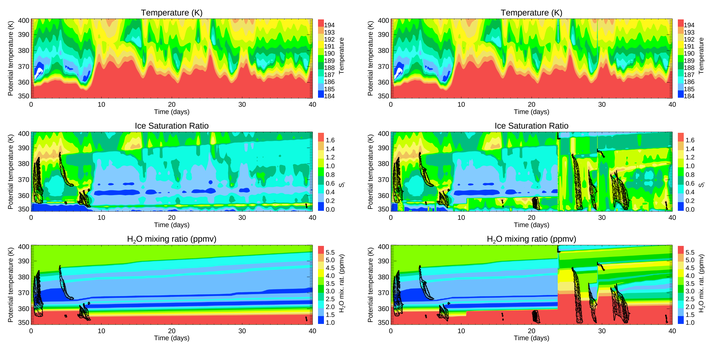
- How important is including detailed microphysics for quantitatively simulationg MLS H_2O concentrations at the tropical tropopause?
- How does the importance of microphysics compare to the influence of other processes, such as gravity waves and convective hydration?
- Do uncertainties in H_2O measurements and model inputs preclude constraining model processes?

Procedure

- 40 day diabatic back trajectories from a 5 by 5 grid of points using GEOS-4 analyses and the GSFC trajectory model (Schoeberl and Sparling, 1995). Generate time-height T curtains along the trajectories and adjust temperatures to match time-average lat-lon-altitude radiosonde values.
- Use a full microphysical model including particle growth, sedimentation, and reevaporation. All calculations here assume “conventional microphysics” (1.6 saturation ratio for nucleation).
- Evaluate convective cloud top thetas from tracing curtains through 3-hourly satellite imagery, adjusting satellite brightness temperatures to raise cloud tops about 1 km (Sherwood et al, 2004) (figure at left below). Air is saturated to the cloud top theta, with the cloud top determined either by matching the brightness temperature with the local temperature profile (middle figure below for brightness temperatures greater than the profile minimum temperature), or by a mixing scheme similar to Adler and Mack (1983) (right figure below).



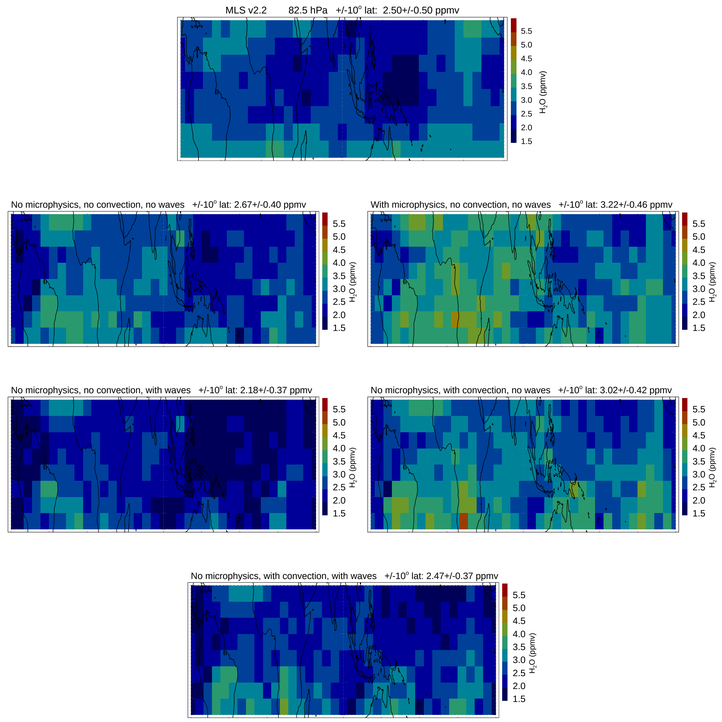
- Figures below show a sample curtain trajectory evolution without (left) and with (right) convection.



Data Products

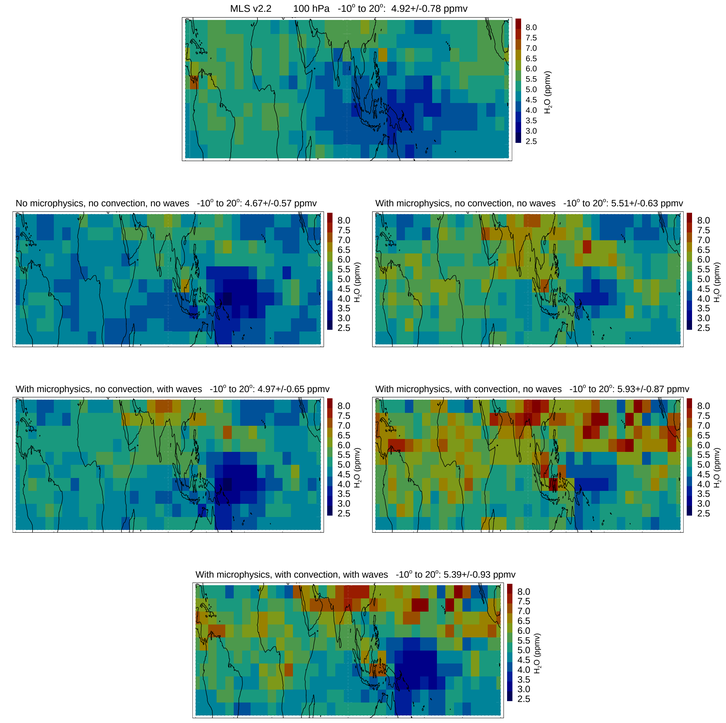
- AURA MLS v2.2 water vapor concentrations at or near cold point (100 hPa for Boreal summer, 82.5 hPa for Boreal winter)

Results: 1. Boreal Winter at 82.5 hPa



- Including detailed microphysics increases H_2O at cold point by $\simeq$0.5 ppmv.
- The impact of microphysics is comparable to those of waves (-0.5 ppmv) and convection (+0.35 ppmv).
- Including microphysics gives higher H_2O at the cold point and creates more longitudinal variability than is apparent in MLS data.

Results: 1. Boreal Summer at 100 hPa



- The effect of microphysics is somewhat larger here (+0.84 ppmv) than in the wintertime simulations.
- The simulations put too much water over the Asian monsoon region (compared to MLS).
- Again, the simulations with microphysics tend to be somewhat wetter than MLS at the cold point.

Uncertainties

- MLS H_2O: 10–15% precision; uncertainty??
- Temperatures in simulations: 1 K $\simeq$ 0.5 ppmv
- Convective injection: procedure ambiguous when cloud top is above cold point
- Microphysics: conventional theory conflicts with observed ice number concentrations and size distributions; potentially more or less dehydration

Summary

- Compared to simple removal of H_2O in excess of saturation, including detailed microphysics increases humidity at the cold point by $\simeq$0.5–0.8 ppmv because supersaturation is permitted and reevaporation of ice crystals provides a water vapor source.
- Given uncertainties in H_2O measurements and uncertainties in simulations (e.g., temperatures and cloud-top heights), comparisons with tropical mean water vapor measurements alone cannot constrain cloud processes.
- Comparisons with MLS do indicate that the model (with microphysics) produces too much geographic variability in H_2O concentration at the tropopause.
- Detailed representation of microphysical processes is critical for simulating cloud properties and radiative effects.